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13. ABSTRACT *(Maximum 200 words)*
GROUND WATER AT RMA HAS BEEN FOUND TO CONTAIN VARYING AMOUNTS OF ORGANIC CONTAMINANTS. SEVERAL BENCH-SCALE TREATABILITY STUDIES HAVE BEEN CONDUCTED TO IDENTIFY TREATMENT PROCESSES WITH A HIGH POTENTIAL FOR REMOVING THE ORGANIC CONTAMINANTS. ONE SUCH PROCESS INVOLVES THE COMBINED USE OF ULTRAVIOLET LIGHT (UV) AND OZONE. THE UV/OZONE PROCESS PROVED VERY SUCCESSFUL IN BENCH SCALE STUDIES ON RMA GROUND WATER. TO FURTHER DEMONSTRATE THE POTENTIAL OF THE UV/OZONE PROCESS, A 1,000 GPD ULTROX FIELD UNIT WILL BE ACQUIRED AND SET UP AT RMA. AN EIGHT WEEK STUDY WILL BE CONDUCTED USING THE ULTROX UNIT TO TREAT GROUND WATER FROM WELLS AT RMA. DATA OBTAINED IN THE STUDY WILL BE USED TO DEVELOP A DESIGN FOR A FULL-SIZE PILOT PLANT ALONG WITH ESTIMATED COSTS FOR THE SYSTEM.

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TEST PLAN

FOR

LIMITED SMALL-SCALE FIELD STUDY

(ULTRALVIOLET/OZONE PROCESS)

by

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INTRODUCTION

1. Groundwater at Rocky Mountain Arsenal (RMA) has been found to contain varying amounts of organic contaminants. Several bench scale treatability studies have been conducted to identify treatment processes with a high potential for removing the organic contaminants. One such process involves the combined use of ultroviolet light (UV) and ozone*. The UV/ozone process proved very successful in bench scale studies on RMA groundwater. To further demonstrate the potential of the UV/ozone process, a 1,000 gpd ULTROX field unit will be acquired and setup at RMA. An eight week study will be conducted using the ULTROX unit to treat groundwater from wells at RMA. Data obtained in the study will be used to develop a design for a full size pilot plant along with estimated costs for the system.

OBJECTIVES

2. The ULTROX unit is a field scale treatment system which will be used to demonstrate the feasibility of removing organic contaminants from RMA groundwater at a 1,000 gpd rate using the UV/ozone process. The objectives of this study are as follows:

a. Assess the potential of UV/ozone process to remove organic contaminants from RMA groundwater in a field scale continuous flow system.

b. Determine the optimum operating conditions for the uv/ozone system.

c. Define modifications in procedures or design that should be evaluated.

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*Buhts, et al, "Evaluation of Ultraviolet/Ozone Treatment of Rocky Mountain Arsenal (RMA) Groundwater (Treatibility study) March 1977.

d. Obtain the necessary information from the field scale equipment for design of full size pilot plant including estimated operating and maintenance costs.

MATERIALS AND METHODS

Equipment

3. The ULTROX field unit was designed to demonstrate on a scale larger than bench size, the practicality and cost-effectiveness of UV/ozone oxidation for removal of organics. The pilot plant is designed to be transported to a water treatment site and to operate on a sidestream of the polluted water.

4. The following operational parameters can be varied in the pilot plant: (1) UV light, input and intensity, (2) ozone introduction, (3) mixing, and (4) water flow characteristics. The UV/ozone reactor assembly drawing is presented as Figure 1. The pilot plant reactor is 28 inches wide by 45 inches long by 45 inches high and is fabricated from 304 stainless steel, which is passivated and electropolished to reduce chemical attack and increase UV reflectivity.

5. The number of operating stages within the reactor can be varied from one to six by the use of internal baffles. The reactor can accomodate up to 30, SL36G, low pressure, UV lamps. From 0 to 30 lamps can be turned on during a test run. Ozone is uniformly diffused from the base of the reactor by 48, spherical, porous spargers, which generate gas bubbles of >2.5 mm diameter to obtain maximum mass transfer of the oxygen/ozone mixture.

6. Ozone will be provided by a Welsbach ozone generator of 4 lb/day capacity. Power input to and ozone output from the ozone generator will be carefully monitored through use of an extensive metering system.

Operation

7. Approximately 24 test runs (3 per week for 8 weeks) will be made using the ULTROX system. Each run will last approximately 5 hours and will be made using only one set of operating parameters. Additional time during each week will be used for test equipment calibration, maintenance, and sample analysis.

8. Initial operating parameters will be determined by extrapolation from earlier bench test work. After the initial run, an optimization program will be used to determine future operating parameters. The optimization program is a computer program that requires inputs of the test conditions (e.g., flow rate, effluent analysis, pH, temperature, etc.) and it outputs a statistically determined set of new operating parameters. Test conditions for each run will be inputed into the program at the conclusion of each run. The program will output the operating parameters to be used for the next run. At the conclusion of the test program, the computer program will provide the optimum operating parameters (minimum power usage and maximum flow rate) for the system to produce an effluent of specified quality (probably based on DIMP removal).

9. The operating variable to be examined include:

(a) O_3/H_2O mass flow rates
(b) UV lamp locations
(c) Number of UV lamps per stage
(d) O_3 concentration

The optimized values for these parameters will allow for the definition of ozone requirements and the number and location of UV lamp placements in a full-sized pilot plant.

Sampling

10. Sampling of influent and effluent water in the system will be conducted at 15 minute intervals during each run. TOC analysis only will be run on the samples until such time as the system reaches steady state conditions. Samples taken after that time will be analyzed for several different parameters (Table 1). Not all analysis will be performed on each sample due to time and laboratory limitations; however, sufficient analysis will be performed to provide an extensive characterization of the influent and effluent water for each test run. Exhaust gas analysis will be performed periodically during each run to determine if any volatile organics are escaping.

SCHEDULING

11. A time schedule for completion of the UV/ozone field unit testing program is presented in Figure 2. Test plan development is scheduled for completion by 31 May 1977. The ULTROX unit will arrive at RMA on 6 June 1977. Two weeks have been scheduled for equipment installation and testing, operator training, and system calibration. After the equipment has been thoroughly checked, an eight week optimization testing program will begin. Additional time (approximately three weeks) will be available for further testing with the ULTROX unit if needed. Data evaluation and report preparation are scheduled to begin in mid-August. Report finalization and review will be conducted during the last two weeks in September. The final report is due 1 October 1977.

SAFETY

Ozone

12. The maximum allowable concentration (MAC) of ozone is 0.1 part per million by volume of air (ppm/v) for continuous exposure under occupational conditions (8 hrs. per day) as was established by the American Council of Governmental Industrial Hygienists*. This level is considered safe. Exposures to ozone at this level or below can be tolorated without harmful effects. Ozone concentrations above the MAC level can also be tolerated for limited periods as shown in Figure 3. The non-symptomatic region in Figure 3 represents exposure times to at least 0.1 ppm/v ozone concentrations leading to no coughing, eye-watering or other symptons of excessive exposure to ozone. The conditions represented this region are also considered completely safe. Thus, an eight-minutes exposure to 1.0 ppm/v ozone and a one-minute exposure to 4 ppm/v ozone fall in this region and can be tolerated with no side effects. The non-toxic region in Figure 3 represents conditions under which exposure to ozone produce symptoms of irritation but are non-toxic. This region includes a one-hour exposure to 8 ppm/v and a ten-minute exposure to 30 ppm/v ozone. More severe exposures fall into the toxic regions. The low threshold odor level (TOL) of ozone 0.01 to 0.02 ppm/v allows the timely detection of ozone in most cases. However, instruments should be used for reliable detection of critical ozone concentrations.

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* American Conference of Governmental Industrial Hygienists, Arch. Inc. Health 11, 521 (1955)

UV Light

13. Exposure of the eye to 2537 Å radiation will cause irritation at a minimum level of 35 $mW\text{-}min/ft^2$, but the actual value may vary for different people. The amount of blood in the mucosae of the eye is an important factor as blood is an absorber of radiation at 2537 Å and therefore will act as a protective screen.

14. The American Medical Association (AMA) has completed a list of maximum safe exposures to UV radiation of 2537 Å wavelength.

Exposure	Safe Intensity ($\mu W/cm^2$) (measured on the base)
24 hr	0.15
18 "	0.2
12 "	0.3
9 "	0.4
7 "	0.5
6 "	0.6
4 "	0.9
3 "	1.2
2 "	1.8
1 "	3.6
30 min	7.2
10 "	21.6
60 sec	216
30 "	432
5 "	2600

The AMA considers a dose of 216 $\mu W\text{-}min/cm^2$ on the unprotected face to be the maximum safe exposure to UV.

15. Full protection against 2537 Å UV is afforded by shields of clear Perspex, ordinary spectacles, Crookes ultraviolet absorbing glasses, or thick orange-colored cellophane eye shields. All personnel who work in the vicinity of the equipment containing a UV source must wear pro-

tective glasses. If irritation to the eye does occur due to inadvertent exposure to UV, a few drops of thin liquid (medicinal) paraffin (known as Paroleine) should be placed in each eye. The paraffin will not arrest the inflammation but will greatly relieve the pain.

Figure 1

Assembly Drawing

1,000 GPD Pilot Plant Reactor

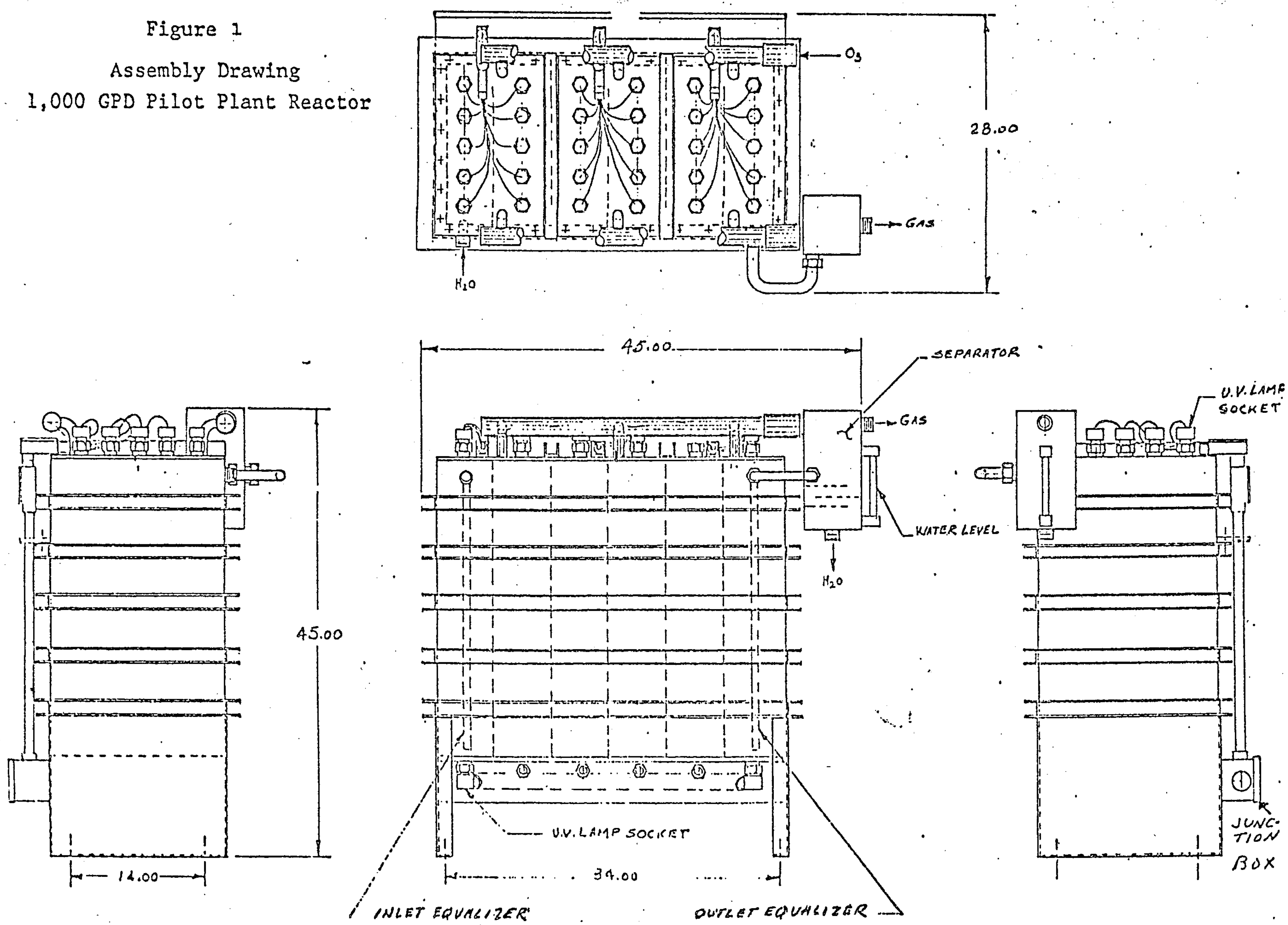

Figure 2.

UV/OZONE FIELD UNIT WORK SCHEDULE

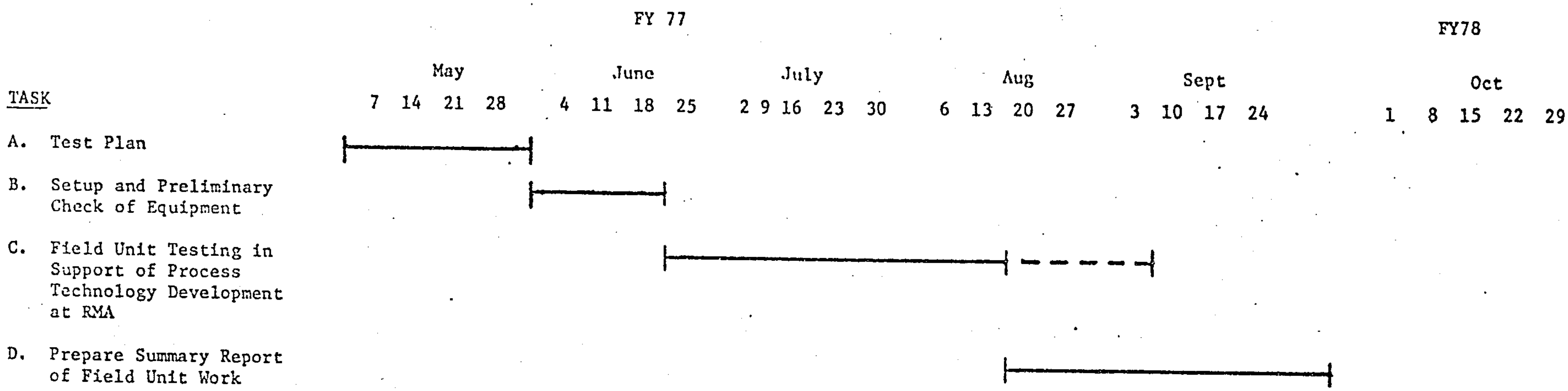

Figure 3

SOURCE: "PROLONGED OZONE INHALATION AND ITS EFFECTS ON VISUAL PARAMETERS", J.M. LAGERWERF, AEROSPACE MEDICINE, 36, 6-63.

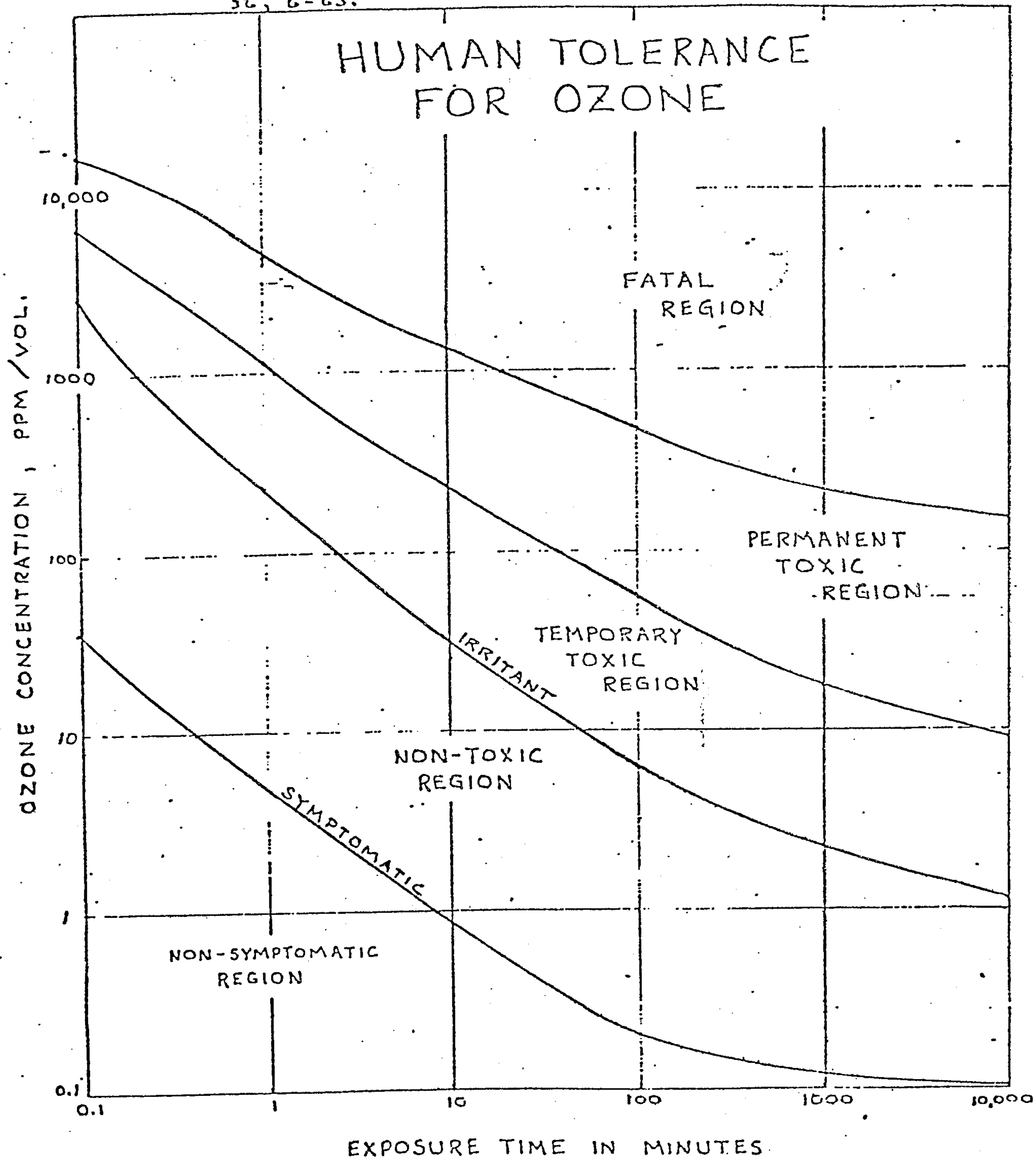

Table 1.

Chemical Analysis to be Performed on Samples from the Limited Small-Scale Field Study

Organic*	Others
DIMP	TOC
DCDP	Total dissolved solids
Pesticides	Conductivity
Organosulfer Compounds	Chloride
	Fluoride
Metals	Hardness
Iron	Alkalinity
Lead	Sulfate
Mercury	Phosphate
Arsenic	Nitrate
Manganese	pH

* To be performed by Materials Analysis Laboratory Division (MALD) at RMA.